# DRDC Power & Energy S&T Option Analysis and Recommendations

*A Response to Cross-Cutting Client S&T Requirements*

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# Abstract

This Document Report on an option analysis and ensuing recommendations for the way-forward for DRDC Power and Energy (P&E) S&T activities at the request of ADM(S&T). This request also coincides with the development of the DND/CAF Defence Operational Energy Strategy (DOES), which is a Level 0 (L0) initiative led by ADM(IE) that identifies specific energy-related targets to be achieved by DND/CAF with the aim of achieving greater operational energy efficiencies while maintaining, or improving, existing DND/CAF capabilities. The option analysis and subsequent recommendations are based on an assessment of the current state of P&E S&T activities within DRDC as well as consultations with strategic documents (including the DOES), the Canadian Joint Operational Command (CJOC), and the DRDC Directorates of the Army, Air Force and Navy portfolios. Four scenarios were investigated for the option analysis, which ranged from maintaining the status quo with current resources to having a formal program structure with significantly increased resources.

Based on the consultations, option analysis, and the anticipated continuing constraints on budgetary resources, the following recommendations are made:

1) It is recommended that a new Power and Energy Program be identified with its own Intermediate Outcome and Immediate Outcomes (Deliverables), to fulfill Horizon 1 and Horizon 2 client S&T requirements while taking into account the intents of the DOES (Option 3);

2) It is also recommended that capabilities in the P&E domain be developed within a program structure should additional resources become available (Option 4). This will enable DRDC to meet longer-term client P&E S&T requirements (Horizon 3) and to allow the engagement of subject areas that are sensitive/classified/strategic/unique in nature (e.g. directed energy weapons) as well as to anticipate emerging/disruptive technologies in this domain; and

3) Any increase in resources and program activities, as described in Option 4, should be planned in a measured and incremental manner against capabilities that exist and those which may be needed within DRDC while taking into account the ability to execute MOU agreements with external partners, and client S&T requirements.


# Significance to Defence and Security

Within the Defence and Security context, P&E is a cross-cutting issue, which underpins DND/CAF operational capabilities across a variety of platforms and spectrum of operations. In 2010–2011, the DND/CAF had a total recurring energy cost of $538 million, which is projected to reach a recurring cost of $1.1 billion by 2031 with significant implications for energy security and operations. Thus, addressing client P&E S&T requirements within DRDC responds directly to objectives 1 and 4 of the DRDC Defence and Security S&T strategy, which states “Build agile and adaptable forces to carry out missions across a wide spectrum of operations” and “Develop and implement solutions to maximize the affordability and sustainability of DND and the CAF”, respectively.

# Résumé

Ce document présente une analyse d'options et les recommandations qui en découlent quant aux prochaines étapes des activités de S & T de RDDC en matière de puissance et d'énergie, à la demande du SMA(S & T). Cette demande coïncide avec l'élaboration de la Stratégie énergétique opérationnelle de la Défense (SEOD) du MDN/des FAC, une initiative de Niveau 0 (N0) dirigée par le SMA(IE) qui établit les cibles énergétiques que doivent atteindre le MDN/les FAC pour réaliser de meilleures économies d'énergie opérationnelles tout en maintenant ou en améliorant les capacités existantes du MDN/des FAC. L'analyse d'options et les recommandations qui en découlent se fondent sur une évaluation de l'état actuel des activités de S & T en matière de puissance et d'énergie au sein de RDDC et sur la consultation de documents stratégiques (y compris la SEOD), du Commandement des opérations interarmées canadiennes (COIC), et des directions des portefeuilles de l'Armée, de l'Aviation et de la Marine au sein de RDDC. Quatre scénarios ont été examinés dans le cadre de l'analyse d'options, allant du maintien du statu quo avec les ressources actuelles à la création d'une structure de programme officielle dotée de ressources considérablement accrues.

En fonction des consultations, de l'analyse d'options et de la poursuite prévue des réductions budgétaires, les recommandations suivantes sont formulées. On recommande:

1) l'élaboration d'un nouveau programme de puissance et d'énergie comprenant ses propres indicateurs intermédiaires et résultats immédiats (livrables), pour répondre aux besoins en S & T des clients des horizons 1 et 2, tout en tenant compte des intentions de la SEOD (option 3);

2) que les capacités dans le domaine de la puissance et de l'énergie soient développées en une structure de programme si des ressources supplémentaires deviennent disponibles (option 4). De cette façon, RDDC pourra répondre aux besoins à long terme des clients S & T en matière de puissance et d'énergie (horizon 3), permettre l'exploration de domaines délicats/classifiés/stratégiques/uniques en leur genre (p. ex. les armes à énergie dirigée) et prévoir les technologies nouvelles/perturbatrices dans ces domaines;

3) que toute hausse de ressources et d'activités de programme, comme il est décrit à l'option 4, soit planifiée de manière raisonnable et progressive en fonction des capacités qui existent et de celles qui pourraient être requises au sein de RDDC, tout en tenant compte de la capacité d'exécuter les protocoles d'ententes avec les partenaires extérieurs et des besoins S & T des clients.

# Importance pour la défense et la sécurité

Dans le contexte de la défense et la sécurité, la puissance et l'énergie sont des thèmes transsectoriels qui servent de fondement aux capacités opérationnelles du Ministère de la Défense nationale / des Forces armées canadiennes (MDN/ FAC) sur diverses plateformes et dans un éventail d'opérations. En 2010-2011, le coût récurrent de l'énergie pour le MDN/les FAC totalisait 538 millions de dollars. On prévoit qu'il atteindra 1,1 milliard de dollars d'ici 2031, ce qui aura des répercussions importantes sur la sécurité énergétique et les opérations liées à l'énergie. Ainsi, en tenant compte des besoins S & T des clients en matière de puissance et d'énergie au sein de RDDC, on se conforme aux objectifs 1 et 4 de la Stratégie S & T pour la défense et la sécurité de RDDC, soit : « Créer des forces agiles et adaptables en vue de mener à bien les missions liées à un vaste éventail d'opérations » et « Élaborer et mettre en œuvre des solutions en vue de s'assurer que le MDN et les FAC soient abordables et durables », respectivement.

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# 1 Introduction

This document is a result of the request by the Assistant Deputy Minister (Science & Technology) (ADM(S&T)) to the Director-General of Science and Technology Force Employment (DGSTFE) to understand the Defence Research and Development Canada (DRDC) Power and Energy (P&E) Science and Technology (S&T) capabilities and to provide a report on recommendations for a way-forward [1]. The subject of P&E is a cross-cutting issue across the defence environments and has gained attention within the Department of National Defence (DND) as reflected by the recent development of the first "DND/CAF Defence Operational Energy Strategy (DOES)". The ADM(S&T)'s request thus coincides with the development of this strategy.

The DOES is a Level 0 (L0) initiative, led by the ADM(Infrastructure & Environment) (ADM(IE)) and co-chaired by the Chief of Force Development (CFD), that identifies specific energy-related targets to be achieved by DND/CAF with the aim of achieving greater operational energy efficiencies while maintaining, or improving, existing DND/CAF capabilities. Consequently, the DOES offers opportunities to better sustain DND/CAF mission continuity as the successful implementation of the DOES targets will result in affordability by reducing operational costs across a full spectrum of domestic and foreign expeditionary operations [2].

The development of the DOES reached a turning point in November 2013 when the Defence Capability Board (DCB) approved a revised set of energy targets to be achieved by all Level 1s (L1s) as P&E impacts all levels of defence and security operations and capabilities throughout the department. These targets were formulated with inputs from DRDC Defence Scientists and span various time horizons depending on the respective projected feasibilities. Although energy is not part of the primary mandate of DND/CAF, DND/CAF uses almost as much as all of the other federal organizations combined; i.e. 42% of all energy used by all the federal organizations, based on gross floor area. DND/CAF had a total recurring energy cost of $538 million in 2010–11, and it is projected to reach a recurring cost of $1.1 billion by 2031 if reduction measures are not taken to curb this trend. In keeping with historical trends, energy demand by the DND/CAF will continue to grow considering future procurement of the new platforms as well as the expected continual reliance on P&E-intensive applications; e.g. C4ISR, directed energy weapons, autonomous platforms and the anticipated increased pace of Arctic and expeditionary operations. Consequently, the recurring cost of P&E for the DND/CAF could reach unsustainable levels, which will have significant implications for Canada's defence mission continuity here and abroad.

The purpose of this document is to report on an option analysis to inform and help DRDC make decisions on program structuring around P&E S&T issues that will impact the DND/CAF. As P&E is cross-cutting across the DND/CAF organization, decisions on the extent of DRDC's commitment to support client S&T requirements, including the DOES, is of significant importance. These decisions will determine the extent of DRDC's investment in P&E S&T activities and, therefore, the extent of DRDC's contributions to helping DND/CAF resolve energy issues with pertinent and strategically tailored S&T capabilities. The option analysis undertaken for this study and subsequent recommendations are based on an assessment of the current state of P&E S&T activities within DRDC as well as consultations with strategic documents (including the DOES), the Canadian Joint Operational Command (CJOC), and the DRDC Directorates of the Army, Air Force and Navy portfolios.

## 1.1 Organization of the Report

This report is organized as follows: Section 1 (Introduction) provides the context in which the option analysis was initiated and undertaken; Section 2 provides context and the important role of P&E within the defence and security environment; Section 3 describes the current state of the main P&E S&T activities within DRDC, which includes why DRDC is involved in this domain as well as how work is delivered on behalf of the DND/CAF clients (largely through leveraging and knowledge access); Section 4 provides the findings derived from consultations with pertinent strategic documents and discussions with the Canadian Joint Operations Command (CJOC) and the DRDC Directorates; lastly, Section 5 describes the option analysis scenarios considered in this study and ensuing recommendations. Supporting materials for the analysis and report are provided in the Annexes.

# 2 Background

Defence operational capability is unquestionably dependent on energy. Energy fuels the fleets for the Army, Air Force and Navy. It provides soldier power and sustains military camps, many of which are located in difficult or extreme environments that typically draw heavily on energy resources. It provides, operates and maintains an extensive range of defence infrastructure consisting of approximately 21,000 buildings and facilities dispersed across the country, and as far north as the High Arctic. Having access to adequate, reliable, affordable energy, when and where it is needed, strikes at the heart of defence operational capability and underpins the operational readiness, sustainability and responsiveness of Canada's national defence and security here and abroad as well as its ability to deliver on its mandate.

DND/CAF is the greatest consumer of P&E amongst all of the Federal departments. The defence energy demands are considerable and the trend is anticipated to grow in the future. Demands for increasing energy supplies, particularly fossil fuels, pose significant financial and budgetary implications. Oil is the fuel of choice for military operations due to its high energy density, fungibility, and global availability. Yet oil prices are highly volatile and unexpected high costs exert significant upward pressure on budgetary spending. One estimate (US) noted that a US$10 increase in the cost of a barrel of oil increases operating costs by roughly US$1.3 billion per year [2]. As energy prices increase, so will opportunity costs. Higher energy costs ultimately reduce funding availabilities that could otherwise be invested in military training, procurement and other operational priorities.

Fuel costs are estimated to be significantly greater when logistical operations necessary for transporting, delivering and protecting fuel are included in the costing. This notion is referred to as the "Fully-Burdened Cost of Energy" (FBCE) and its potentially significant impact on costs has been gaining attention in defence force planning. The FBCE of a number of Canadian Forces military camps in Afghanistan were estimated to vary from 120% to 320% of the fuel commodity price depending on the distances traveled. Fuel transported by air significantly increases the total costs and is the most prohibitive of transportation costs. For example, in an estimate examining the fuel costs to operate Canadian Forces Station (CFS) Alert located in the High Arctic, which is accessible only by aircrafts, the FBCE was estimated to be about 800% of the fuel commodity price. Similarly, an estimate by the United States Department of Defense (US DoD) noted that fuel costs could approach US$400 per gallon after accounting for logistical operations. In an era of fiscal restraint, particularly as the government returns to balanced budgets, the FBCE would mean significantly less flexibility in budgetary spending.

In addition to the financial cost, there exists, more importantly, another facet to P&E for DND/CAF operations. The greatest vulnerability of all associated with a high demand for energy is the cost of human life that may result from the increased risks with manning, equipping and defending heavy logistics supply chains. Increased operational energy demands exert heavier logistics chains that can slow operations, limit manoeuvrability and deployability, burden force structure in combat support, create untenable force protection requirements and expose personnel to serious and unnecessary risks during missions. Though a Canadian study does not exist, a US estimate indicated that roughly half of the tonnage transported in a US deployment was fuel alone [2], which imposes a heavy burden on the combat forces to maintain and protect the logistics

chain. Fuel delivery convoys along vulnerable lines of communication in Afghanistan have often been prime targets for insurgent forces.

Many other complications also exist which may hamper or completely eliminate access to energy. Factors such as geopolitical instability, natural disasters, accidents or overloaded or aging critical infrastructure remain as potential threats to defence energy security. Furthermore, it is clear that the greater the energy demands, the more sensitive the demands are to disruption by these factors.

# 3 Current Situation of DRDC P&E S&T Activities

This section describes the current situation of P&E S&T activities at DRDC, including the reasons DRDC is engaged in this domain, the mechanisms for S&T delivery, brief descriptions of active projects currently in the Army and Air Force portfolios and how these projects align with the DOES targets, as described in sub-section 4.1.

## 3.1 Why DRDC is Doing this Work

The cross-cutting nature of P&E is such that it underpins the DND/CAF operational capabilities across a variety of platforms and spectrum of operations. In addition, it is also cross-cutting as the concepts of generation, storage, distribution, management and integration are common issues and affect the vast majority of platforms. As such, the addressing of P&E S&T client requirements responds directly to objectives 1 and 4 of the DRDC Defence and Security S&T strategy, which states "Build agile and adaptable forces to carry out missions across a wide spectrum of operations" and "Develop and implement solutions to maximize the affordability and sustainability of DND and the CAF" respectively [3].

As generic and ubiquitous as the subject of P&E S&T may seem to the non-experts given the level of activity within industry, academia, other government departments (OGDs) and international partners such as TTCP and NATO (Annex B), the role of DRDC in this domain is critical in ensuring that DND/CAF remains operationally effective while being sustainable and affordable; this has been supported by previous internal reports and Functional Planning Guidance documents where P&E was identified as a "hard" S&T problem [4],[5]. While much S&T work is being done within these external organizations, a targeted approach towards DND/CAF-specific issues remains essential to address DND/CAF-specific needs, which often require specialized P&E solutions; for example, silent watch applications. Furthermore, and more broadly speaking, the P&E S&T domain is wide-ranging and complex, which goes beyond propulsion of platforms and commercial-off-the-shelf (COTS) electrical generation sources; it also includes novel power sources, thermal energy (e.g. co- and tri-generation), energy harvesting, renewable sources and, extends into system-level approaches that incorporate energy storage, distribution, efficiency, management, platform integration and grid/network concepts.

Within DRDC, P&E S&T work has been ongoing for several decades. However, for approximately the last ten years, the P&E S&T group has consisted of only two full-time Defence Scientists who are the DRDC experts in this domain. Despite this limited resource, DRDC has nevertheless been able to provide leadership in addressing the P&E S&T requirements on behalf of the DND/CAF clients with evidence-based impacts (Annex C). In this capacity, the P&E group's role is primarily three-fold:

1) As the Trusted Advisor, DRDC has a history of investigating and providing objective P&E S&T advice and recommendations to the DND/CAF. Considering the complexity of the domain and the wealth of information that is growing rapidly, solely relying on external sources poses a risk that could be debilitating and costly if the information presented to the DND/CAF is biased. The consequences of the lack of objective evaluations of the information are especially severe if the DND/CAF clients do not have the necessary expertise to ensure that the poignant and essential

questions are being asked. Furthermore, through its continuous engagement with clients, the P&E group has developed the corporate memory of P&E issues within the DND/CAF, which is invaluable in ensuring knowledge and experience continuity and efficient use of limited resources dedicated to P&E S&T challenges;

2) As the Risk Mitigator, DRDC minimizes risks to the extent possible for technology use as well as provides "smart buyer" advice to the DND/CAF clients. Without mitigating the risks in these areas, potential significant impacts on operational effectiveness exist such as technology reliability issues and unnecessary constraints placed on resources that could be reprioritized for use elsewhere; and,

3) As the Knowledge Integrator and Tech-Watcher, DRDC is inherently positioned to respond to s*ensitive/classified/strategic/unique* P&E issues; e.g. arctic power and energy (strategic) [6] and directed energy weapons (sensitive/classified/unique).

## 3.2 How DRDC is Delivering this Work

At present, the majority of P&E S&T work is being delivered by the P&E S&T group, which organizationally belongs to DRDC Atlantic. The group consists of two full-time Defence Scientists embedded at the National Research Council (NRC) of Canada in Ottawa, and at present, there is no formal P&E program structure to their activities. With limited FTE capacity and funding resources, much of their work is conducted through collaboration and knowledge access by leveraging various external sources as described below.

### 3.2.1 Sourcing Strategy

Within the DRDC construct of defence and security S&T delivery, the P&E group uses an integrated science approach that is founded upon collaborative networks of national and international partners to access the required knowledge and expertise to address DND/CAF client requirements. The P&E group has a well-established history of successfully leveraging external resources and expertise among partners to the benefit of the DND/CAF (Figure 1 and Annex C).These external partners are divided nationally and internationally as follows:

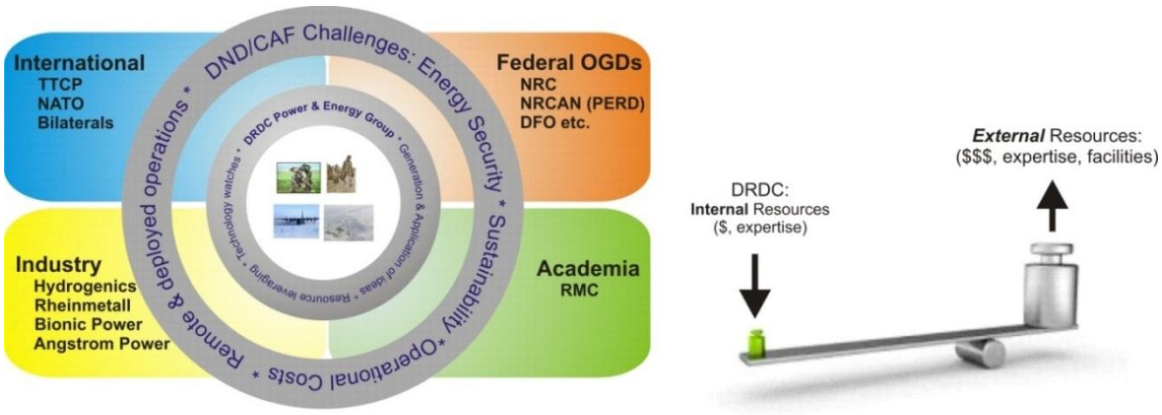


*Figure 1: Engagement and S&T delivery mechanism of external resources by the DRDC P&E group through collaboration/knowledge access (left) and leveraging (right).*

**National Partners**

Domestically, the various projects exploit Canadian expertise through external sources and partners such as OGDs, industry and academia.

a) **Other Government Departments:** The DRDC P&E group collaborates with various Canadian government organizations to leverage their expert knowledge and to access external funding sources (cash) and in-kind contributions that have augmented DRDC funding investments over the years. In particular, in the spirit of the Federal Laboratories Integrated Governance (FLIG), DRDC has had a long-standing collaboration with the NRC of more than 20 years and more recently, DRDC has established another long-standing collaboration with CanmetENERGY (NRCan) for which an umbrella MOU for P&E S&T activities is currently being sought. The OGDs which have been engaged include Industry Canada, Environment Canada, Department of Fisheries and Oceans, the Geological Survey of Canada, Atomic Energy of Canada Limited (AECL), provincial laboratories such as the Institut de recherche d'Hydro-Québec (IREQ), etc. The engagements of OGDs occur through direct taskings, joint proposals for external funding (e.g. Program for Energy Research and Development (PERD)), Government of Canada Clean Energy Funds and participations on external panels and working groups (e.g. the defence scientists participate on multiple PERD panels and working groups such as Industry Canada's Interdepartmental Hydrogen and Fuel Cell (H2FC) Committee). The successful engagement with PERD is especially noteworthy as is evidenced in the cumulative amount of more than $3M in funds and in-kind contributions received since 1999 and, more importantly, the direct positive impacts to the DND/CAF clients (Annex C). Additionally, consultations with Atomic Energy of Canada Limited (AECL) and provincial laboratories such as the Institut de recherche d'Hydro-Québec (IREQ) have proven to be essential in expanding DRDC S&T capabilities to address the broad spectrum of requirements of DND/CAF P&E S&T [7].

b) **Industry:** DND depends on industry to provide energy products and power sources for a multitude of equipment from small batteries for soldier devices to 500-kilowatt electric generators to full propulsion systems for ships, aircrafts and ground vehicles. Through the process, DRDC uses its expertise and plays a vital role as an independent third party to provide DND with objective evaluations of industry products. Because of the continuous evolutions in power sources and new vendors in this marketplace, DRDC is keeping abreast of rapid industry S&T developments as prototypes to new products used in military equipment emerge.

   DRDC also leverages the S&T capacities in the industry to develop technologies of importance to defence. An example is the current contract with Rheinmetal Canada Inc. in St. Jean, Québec, to develop an integrated soldier power/data backbone, which is the basis of the Army's Integrated Soldier System Project (ISSP) Cycle III procurement requirements. The international engagement has also allowed DRDC to promote Canadian industry in this sector and in some cases, has helped Canadian industry access US programs and investment. For example, in the battery and fuel cell sector, the US Army has been the biggest customer over the last ten years for several companies DRDC initially supported.

c) **Academia:** When S&T of low maturity is to be performed, DRDC looks to expertise within academia to deliver project objectives. In the past, this has occurred by supporting programs, and/or providing funding such as the Federal Government PERD program and DRDC's own

internal programs. For example, the Royal Military College (RMC) has been DRDC's main support over the last ten years and has conducted S&T of interest to DRDC in this domain. Over the last 25 years, DRDC has also leveraged international academia for additional S&T work such as that on fuel reforming and fuel cell technologies. The international accesses have resulted in patents, which would otherwise be unfeasible, such as compact methanol reformers for fuel cells being developed in the US. The multiplying effects of international collaborations are significant, as is demonstrated in the added benefits of the training of students, and as importantly, on the awareness of energy-related technologies to military officers attending RMC who later transition to DND/CAF roles.

**International Partners**

International partnership is a key means to access the significant S&T investment by Canada's allies in the P&E domain. The partnership with the US is particularly important since the US places important standing to P&E as they identify it as a key enabler for their current and future platforms. The international partnership is primarily enabled (1) through TTCP under Materials Technical Panel 8 (MAT TP8) Power & Energy – Materials and Systems, (2) in NATO with the NATO Army Armaments Group Land Capability Group Dismounted Soldier Systems (NAAG LCGDSS), and (3) via NATO Science and Technology Organization (STO) working groups under Sensors & Electronics Panel (SET), Applied Vehicle Technology Panel (AVT) and Joint Systems & Analysis Group (JSA). Significant contributions and access have resulted in several NATO Standardization Agreements (STANAGs) on soldier interoperability, which is currently expanding into a NATO operational energy strategy to sustain camp, forward operating bases and the military in the Adaptive Dispersive Operations (ADO). Information access through TTCP into allies' larger programs working in several energy specialties and burden sharing assignments have resulted in direct cost savings to DRDC program ($250K in 2013/14).

Additionally, key bilateral agreements such as North American Technology and Industry Based Organization (NATIBO) are important as the US has operational energy as a major technology focus with a very robust industry sector in which Canada procures most of its energy storage (such as batteries) and electrical generation equipment (e.g. generators). As Canada depends on US industry sector in this domain, bilateral engagements provide DRDC direct accesses to strategic (secret) developments in US military S&T investments.

### 3.2.2 Strategic Influence

In addition to leveraging and accessing expertise and funds from sources external to DRDC, DRDC also plays an important role in influencing planning within other departments to strategic benefit by participations in working groups, PERD and direct engagements of OGD groups in DRDC projects. The most recent example of such an influence is in the domain of Northern/Arctic P&E. DRDC's involvement in this S&T area stems from the Royal Canadian Air Force (RCAF) project at CFS Alert (03ab) and the Army project on deployed camps. While OGD partners have been eager to further work in Northern/Arctic P&E, their options have been limited as, until recently, they neither had the mandate nor the resources to be able to do so in a significant way. Recognizing that multiple stakeholders were interested in working together albeit with very limited resources, in July 2013, DRDC initiated, and co-organized with NRCan (CanmetENERGY) the "DRDC Northern/Arctic Power and Energy" workshop, which involved

multiple OGDs[1] and DND/CAF participants.[2] The objective of the workshop was to explore common interests with external partners to advance S&T solutions and strategies to reduce fossil-fuel dependence and costs for DND/CAF operations as well as civilian communities in northern/arctic regions, which also share the same energy constraints. A key DRDC contribution of this workshop was that of a Cabinet submission to seek new funding for P&E S&T activities in remote northern/arctic locations, which was to be led by CanmetENERGY [8], [9]. Since then, a "Northern and Remote Energy" technology area has been included within the "NRCan Energy Innovation Program" submission to Cabinet planned for the Fall of 2014 [10].

## 3.3 Current Projects

The following table is a summary of the currently-funded Army and Air Force projects within DRDC as identified in the signed Program briefs and Portfolio charters for FY2014/15.[3] For detailed descriptions of these projects and how they relate to their respective program outcomes and deliverables please see Annex D.

## 3.4 Alignment of DRDC P&E S&T Activities with DOES

The current level of effort undertaken for S&T activities within the Army and Air Force portfolios as described in Section 3.3 aligns with DOES Targets 1, 6, 7 and 1, 2, 6 respectively (as shown in Figure 2 below on Page 11). For specific target descriptions, please see the DOES energy targets in sub-section 4.1 below.

That there is alignment with the DOES energy targets and Intermediate Outcomes from the various portfolio programs is to recognize DRDC's role in shaping the targets with expert participations in the DOES primary and sub-working groups. Furthermore, it is to be noted that Figure 2 highlights gaps within the current DRDC portfolio structure as a consequence of recent restructuring of key organizations within DND such as ADM(Mat) and ADM(IE) for which P&E is an essential capability. An example of this is the consolidation of all infrastructure assets including those in the arctic and ensuing responsible authority within ADM(IE), which will affect all services and environments (including those for CJOC).

[1] NRCan (CanmetENERGY, PSCP, CanmetMINING), NRC, Aboriginal Affairs and Northern Development Canada (AADNC), Sustainable Development Technology Canada (SDTC), Industry Canada (IC), Atomic Energy of Canada Limited (AECL), Canada Mortgage and Housing Corporation (CMHC).
[2] RCAF, DF&L and CJOC.
[3] It is to be recognized that other projects exist that are P&E-related and undertaken to a lesser extent elsewhere within DRDC. However, collating this information has been difficult given the stove-pipe nature of the project structure.

*Table 1: Currently-funded P&E S&T projects.*

| **Portfolio** | **Project** | **Funding status** | **Clients** | **Leverage** | **Significance for Defence** |
|---|---|---|---|---|---|
| Army | Soldier Systems Effectiveness | Funded to FY 2015/16 | • ISSP major capital project;<br>• Director Land Requirements 5 (DLR 5);<br>• Tactical Command, Control and Communication System (TCCCS); and<br>• Canadian Special Operations Forces Command (CANSOFCOM); | • NRC (MOU)<br>• International agreements (TTCP, NATO, bilaterals) | • Optimize Life Cycle, integration to ISSP and CF logistics chain (battery recharging/resupply)<br>• Management (LCM) for power (batteries etc.) and power/data weight/cost.<br>• Ensure commonality with allied systems (NATO STANAGs) (industry standards)<br>• CF Smart buyer as power most expensive LCM cost for soldier platforms. |
| Army | Manoeuvre through Adaptive Dispersed Operations | Funded to FY 2018/19 | • Modern Power Sources & Shelter Replacement Capital Acquisition;<br>• Director Land Requirements 7 (DLR 7);<br>• CJOC (Energy and Environment) | • NRC, NRCan (MOU)<br>• International agreements (TTCP, NATO, bilaterals) | • Terrorist and supply chain threat, cost and time on station (extending)<br>• CF Smart buyer (several options available) for army sustainment in operation. |
| Air Force | Force Generation and Support | Funded to FY 2014/15 | 1 Canadian Air Division | • NRC;<br>• CanmetENERGY;<br>• Geological Survey of Canada;<br>• Environment Canada; and<br>• Department of Fisheries and Oceans | • Affordability and sustainability for arctic infrastructure<br>• Alternative P&E options towards reducing the reliance on fossil fuels<br>• Reduced wear and tear on military aircraft for OP Boxtop<br>• Reprioritization of flight assets due to reduced fuel-use at CFS Alert (reduced OP Boxtop flights) |

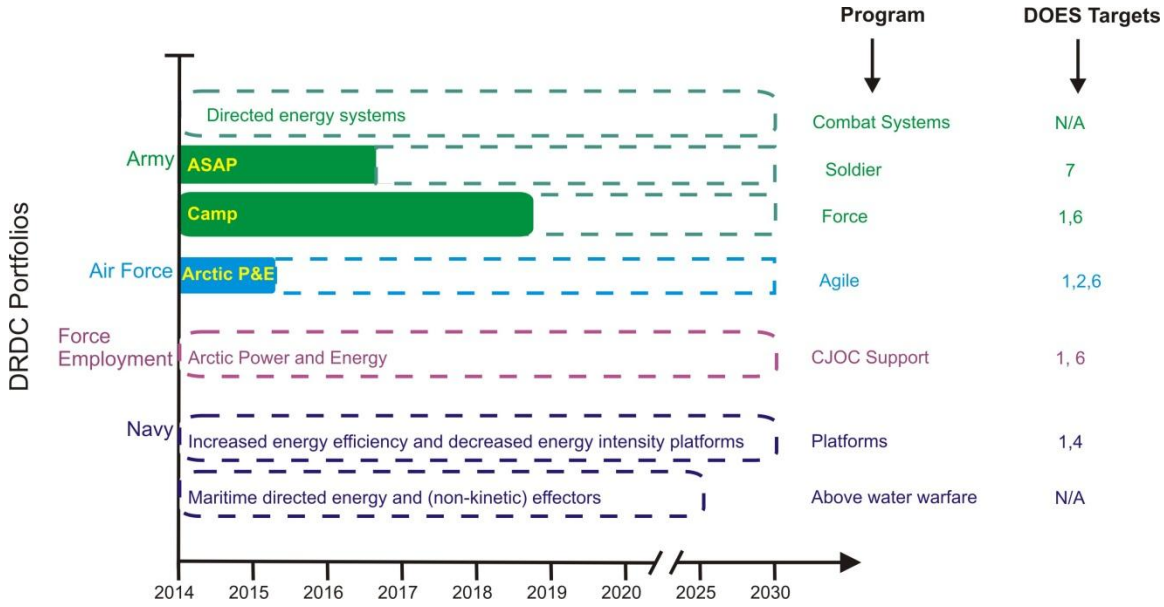


*Figure 2: Alignment with DOES targets of currently-funded projects (solid colours) and identified gaps in P&E S&T activities (dashed lines represent P&E activities, which have been identified in the respective programs but are not currently funded) within the respective portfolios.*

# 4 Consultation with Documents, Force Employer and DRDC Directorates

To perform the option analysis for this document, relevant strategic documents [2]–[6]; [11]–[14] were consulted as well as the Force Employer (CJOC) and the DRDC Directorates representing the Force Generators (Army, Air Force and Navy) [15]–[18].

## 4.1 DND/CAF Defence Operational Energy Strategy (DOES)

Recognizing the importance of operational energy, DND/CAF has developed the DOES, which outlines ten energy targets for all DND L1s to achieve. The DCB subsequently endorsed the energy targets in November 2013, which conveys an important message to the whole DND/CAF regarding energy sustainability and affordability for its operations. In defending and protecting Canada and North America and in contributing to international peace and security, DND/CAF along with its allies recognizes energy as a key critical enabler and an operational imperative that make achieving the mission possible. DND values energy as a strategic resource that strengthens operational resilience and assures energy security by limiting the effects of vulnerabilities.

The DOES marks a new policy perspective on energy issues (one that considers energy holistically) within the DND/CAF across the broad spectrum of defence activities in the department. The DOES provides a common vision and goals to collectively better manage energy as a strategic resource for the DND/CAF now and in the future. It outlines ten energy targets for DND/CAF to achieve, which span various timelines and a spectrum of assets including platforms and vehicles, major power and heating generation equipment, and infrastructure in the context of both domestic and deployed operations. Given its potential for enhancing environmental initiatives, it is also streamlined with the Defence Environmental Strategy [19] to provide additional support where possible for defence to meet its sustainability goals. Though the DOES is not yet official, nine of the ten energy targets outlined in the DOES have nevertheless been endorsed by DCB in November, 2013. Energy target 5 was not submitted to the DCB for endorsement as it relates to commercial vehicle designs, which the DOES Expert Panel believed was not within Defence's purview to influence. The ten energy targets are:

1. **Energy Measurement and Management:** By 2030, to the maximum extent practicable, bases, platforms and expeditionary power and heating generation equipment shall employ an automated data acquisition, recording and metering system that measures the consumption of fuel from all sources;

2. **Demand Reduction – Buildings:** By 2030, all CF Bases and Stations, as whole entities, will reduce through efficiencies their energy use intensity (EUI) by 20% from 2005–2006 levels;

3. **Critical Infrastructure:** By 2030, all defence critical equipment, infrastructure and services will have reliable back-up power systems able to sustain independent (off-grid) operations for a minimum period of 14 days;

4. **Military Platforms and Fleet:** By 2025, the CF will have reduced the class fuel consumption rate by 10% from those detailed in the Fuel Consumption Unit (FCU) tool developed by ADM(Mat) and validated in 2012;

5. **Improvement of Commercial Vehicle Fleet Efficiency:** By 2025, based on a 2010 baseline, defence will double the average mileage achieved per litre of petroleum used in its commercial vehicle fleet. *(Note: this target was not submitted to the DCB)*;

6. **Demand Reduction – Military Camps:** By 2030, per person, reduce the energy consumption required to produce main and deployed military camp services (heating, power generation, sewage treatment, water supply, etc.) during the conduct of domestic and expeditionary operations by 50%;

7. **Increase in Energy Efficiency for Soldiers:** By 2030, all individual dismounted soldiers will be independent from the logistics chain for energy resupply for at least 72 hours without increasing the soldier's burden;

8. **Alternative Energy Opportunities:** By 2016, the CAF will have certified the processes by which suitable advanced, "drop-in" alternative liquid fuels, that meet Canadian military specifications, can be used in each of its tactical (non-commercial) platforms and vehicles;

9. **Force Planning and Procurement:** From 2018, tools to account for and analyse energy consumption and costs are to be incorporated into all strategic modeling and simulation (M&S) programmes that are used for force planning, option analysis and requirements development; and

10. **Procurement – Energy Key Performance:** From 2018, the procurement process for equipment and infrastructure (capital and O&M) will incorporate energy usage and fuel economy over the life cycle of the asset as a key performance criterion.

## 4.2 Canadian Joint Operations Command

Being a force employer, Canadian Joint Operations Command (CJOC) is one of the principal clients of the Force Employment (FE) portfolio. Consequently, responding to CJOC's requirements is of prime importance. Consultations with CJOC to understand their requirements include understanding their strategic objectives as outlined in their documents, as well as meeting with them to further obtain details pertaining to current gaps and future needs. The relevant document for this purpose is CJOC's Business Plan for Fiscal Year 2014/15 [20], which with regards to operational energy states:

> *"CJOC will be a leader in advancing an operational energy strategy for all operations. Through the development of the Defence Operational Energy Strategy (DOES), CJOC will promote the advancement of targets related to deployed operations. This will include the development of a CJOC energy strategy directed towards the reduction of fossil fuels on CJOC operations. CJOC will continue its cooperation with ADM(S&T) in the development of technological and cultural solutions aimed at a reduction in the energy and logistical footprint on operations and exercises."*

A cultural solution is a solution of behaviours and mentality/attitude of the staff, both military and civilian, whose beliefs and habits, while instilled into the daily conducts, result in contributions to the solution to the overall problem. CJOC's needs on P&E S&T relate most to the sixth and the seventh targets of DOES targets as listed under sub-section 4.1.

**Deficiencies**

The consultation with CJOC reveals that a very significant deficiency exists overall in P&E planning, use and S&T in the CAF. The main reason is that a military champion does not exist to advance the subject activities and to coordinate concerted efforts for optimal return on investments. Consequently, resources are thinly spread and S&T in P&E is done on an ad-hoc basis and in a stove-piped fashion with no strategic planning, and procurements are conducted without strict objectives on energy efficiencies and limits of acceptability. Unlike Canada, the US has an operational/mobile energy approach that better satisfies their energy needs. The following example, as given by CJOC during the consultation, illustrates the differences between Canadian approach and American approach in the procurement process.

> The US has a program to address fuel efficiencies in the procurement processes of military vehicles/platforms (e.g. aircrafts), where initial financial overheads are accepted in exchange for improved fuel efficiencies, thereby saving money in the long term. Currently, Canada does not have such a program and therefore, the CAF's procurements do not take fuel efficiencies into considerations. Consequently, it is more expensive in the long term to own, maintain and operate a particular vehicle/platform. Furthermore, other serious repercussions arise in certain circumstances. A vehicle/ship that is less fuel efficient requires more frequent resupply which could place the vehicle/ship and the crew in harm's way, as the vehicle/ship may need to navigate through dangerous territories to arrive at the destinations for supplies. Additionally, an increased amount of logistics is required if the vehicle/ship is to be escorted due to a shortage of fuel, thereby reducing flexibility and fighting capabilities.

**Concerns**

One of the concerns expressed by CJOC during the consultation is that a DRDC P&E S&T program does not exist, though the demands warrant such a program. An emphasis for a need in P&E S&T for deployed camps has been expressed in order to ensure that operations are sustainable and capabilities are enhanced with reduced resources. More specifically, fuel consumptions for camps need to be systematically reduced so as to simplify logistics, reduce risks and render operations more efficient. An important consequence of the lack of such a program is the objective study, planning and program formulation for future P&E S&T to properly exploit advanced technology and to satisfy energy needs. It has also been mentioned that the existence of a P&E S&T program will provide further advantages from an organizational point of view as a single Point of Entry within DRDC would exist to structurally mirror the Environments (Army, Air Force, Navy), which is an objective that DOES aims to maintain. This single Point of Entry would facilitate communications for situational awareness and for establishing and maintaining collaborative efforts in this domain.

## 4.3 Army

Compared to the Air Force and the Navy, the DRDC Army portfolio has had a relatively significant S&T investment in P&E in DRDC's projects and continues to have a strong need for knowledge in P&E to satisfy its requirements. An area of research where the Army emphasizes a need for in-house DRDC P&E S&T is that related to dismounted soldier system. Army expresses the importance of developing and maintaining expertise in this area within the Army portfolio and that it is crucial that DRDC invest resources for Horizon 1 (0–5 years) and Horizon 2 (5–10 years) to achieve the objectives of improving soldier effectiveness by increasing protection, weapon effects, mobility, self-sufficiency and resilience while decreasing burden, in an integrated, human-centric soldier system. Improved soldier effectiveness encompasses improved self-sufficiency (without re-supplying for the mission duration) through increased energy efficiency, without adding to the total weight, in an advanced wearable power system that augments a dismounted soldier's performance, autonomy, sustainability and effectiveness in dispersed operations.

Due to resource constraints, and for optimal resource efficiency and effectiveness, Army will leverage the industry for targeted P&E S&T related to other needs, such as C4ISR vehicles and systems, in all of Horizons 1, 2 and 3. Targeted leveraging will help reduce costs and mitigate risks to improve long-term S&T needs while maintaining access to a larger resource and knowledge base. Additionally, developing and maintaining DRDC expertise will be vital in order to ensure that DRDC corporate memory in this area continues to exist and that Army continues to receive objective expert advice on P&E issues. In interacting with the industry, the internal DRDC P&E experts have been the trusted advisors and their expertise will continue to be critical to the success of Army's projects.

In considering both the existing projects as well as future requirements, it is acknowledged that resources dedicated to P&E S&T are deficient in comparison to the extensive amount of work to be undertaken to satisfy future Army needs in all of Horizons 1, 2 and 3. In addition to C4ISR vehicles and systems mentioned above, further requirements in P&E S&T are foreseen for camp power, silent watch/standby watch, energetic weapons, etc. Each of these areas poses its own unique challenges that cannot be resolved without objective advice from DRDC expertise.

## 4.4 Air Force

The Air Force portfolio currently has only one project (03ab) that requires P&E S&T for arctic infrastructure and is a legacy project that will be completed at the end of fiscal year 2014/15. Given recent changes within ADM(IE) to assume arctic infrastructure assets, the portfolio currently does not expect to have any more activities in this area of study nor additional requirements in the new fiscal year and in future years (Horizon 1 to 2). However, it has been expressed that the subject of Unmanned Air Vehicles (UAVs) is cross-cutting and the need exists to enable UAVs to fly longer by being more energy efficient or by having higher energy density.

Though the Air Force is the greatest consumer of P&E amongst the Environments, it was expressed that it does not have influence on P&E issues. As the Air Force procures from the industry, either by renting or by purchase of the aircrafts, the industry has no incentive to satisfy the fuel efficiencies beyond the planned levels as the increased efforts result in additional costs,

which the industry is not willing to incur. Furthermore, the internal community in DND is resistant to changes and innovations that could result in fuel efficiencies and cost savings for such a fixed platform. An example is the resistance of improvement of fighter plane F18, whose technology is that of Vietnam War and where changing the electronics would result in both better technology and a reduction in the overall weight, thereby rendering the plane more fuel efficient with improved combat capabilities. However, attempts by DRDC in the past to implement improvements on the F18 platform have not been accepted.

## 4.5 Navy

The Royal Canadian Navy (RCN) is the second largest consumer of fossil fuels within the CAF, after the RCAF, and their interests are primarily related to improving energy efficiency. The RCN provides direction and details requirements for DRDC via the Maritime Science and Technology Programme Guidance (MSTPG), which is issued annually. While many of the RCN S&T requirements will depend, at least in part, on the availability of adequate P&E resources, only one direction from the MSTPG specifically mentions energy, which states "NP05[4]—Provide scientific advice to develop energy initiatives and technologies with the specific goal of increasing the energy efficiency while decreasing the energy intensity of RCN platforms". Though the RCN has established a timeframe such that the goal and its appropriate metric are to be defined by 2015 and initial technology enablers established by 2020, no work currently exists towards this requirement due to limited resources and assessment by the RCN that other requirements are of higher priorities.

For work in Horizon 1, Navy expresses that their current interests are primarily related to improving energy efficiency on current vessels through hull coating and related activities to reduce drag. There may be some S&T requirements on energy distribution in ships, but the proper DRDC role in this area is debated. The consensus on the need for DRDC to develop expertise sufficient to advise the RCN of future class power requirements is not universal, as some believe that such activities are the proper responsibility of the Director General Maritime Equipment Program Management (DGMEPM) in ADM(Mat). It is, however, acknowledged that the cases for work in Horizon 2 and in Horizon 3 may require DRDC expertise as some P&E areas may impact naval operations in the future. These include power requirements related to increased use of unmanned vehicles (UxVs) launched from naval vessels and power storage and delivery requirements for directed energy weapons (DEW). In both cases, DRDC does not possess any such P&E navy-related expertise or experience, and Navy expresses that DRDC expertise may need to be developed to properly provide advice of naval importance in the future. The expertise could be developed via understanding power distributions on existing naval platforms in anticipations of advising on future platform requirements, such as requirements for Canadian Surface Combatants (CSCs), and via leveraging allied partner knowledge base with respect to UxV and DEW energy requirements.

Conflicting reactions have been observed on the issue of P&E. The hesitation and the ambivalence of supporting a P&E S&T program may be a result of a few factors. One factor is that the RCN is both conservative in nature and a small player on the world scale, and the observation is that the RCN does not have the resources and the momentum to pioneer and to

[4] NP – Naval Platform

innovate. The other factor may be due to the concern that a P&E S&T program further creates competition for DRDC resources that may or may not benefit RCN priorities, given the current resource scarcity, the repeated resource reductions in the last few years and the anticipated further reductions in the future.

## 4.6 Summary of Consultations

The consultations of strategic documents as well as with CJOC and the DRDC directorates of Army, Air Force and Navy led to the following observations:

1. P&E is recognized by all sources as a key critical enabler for defence and security operations;

2. Although there is a genuine appreciation and understanding of the cross-cutting nature of P&E and its impact for DND/CAF, it is not considered the top priority in the portfolios;

3. At the DRDC Directorate level, there appears to be support (in principle) for the co-ordination of P&E S&T activities across the portfolios whether a formal program structure is adopted or not. However, with the assumption of "zero-sum" budgetary constraints, concerns were expressed by the Directorates that any increase in P&E S&T activities would inherently translate into divestments in other S&T areas;

4. The majority of P&E S&T activities has had a history of being embedded within the Army portfolio, which continues today and is anticipated to continue with varying tempos of S&T investments in soldier, camp and vehicle platforms over Horizons 1–3. CJOC has expressed a desire to DRDC for P&E S&T guidance for deployed camp operations, which could be leveraged against the Army project Manoeuvre through Adaptive Dispersed Operations (ManADO) efforts. Within the Air portfolio, investment is not anticipated over Horizon 1–2. However, the subject of autonomous aerial platforms is considered cross-cutting and requires a focused effort in Horizon 3. For the Navy portfolio, anticipated P&E S&T requirements are to focus on energy efficiency of naval platforms over the Horizons 1 and 2, with directed energy weapons in Horizon 3. These anticipated requirements are summarized in Figure 3 below;

5. While the Directorates acknowledged an awareness of DOES, there was an unfamiliarity of its energy targets and how the DOES might impact client S&T requirements within their portfolios, which may significantly impact program planning within DRDC on its approval and release; and

6. The DOES will place a greater focus and emphasis on energy sustainability and affordability within the DND/CAF as it ascribes targets across a spectrum of operations and platforms over various Horizons to be met by all L1s within the department.

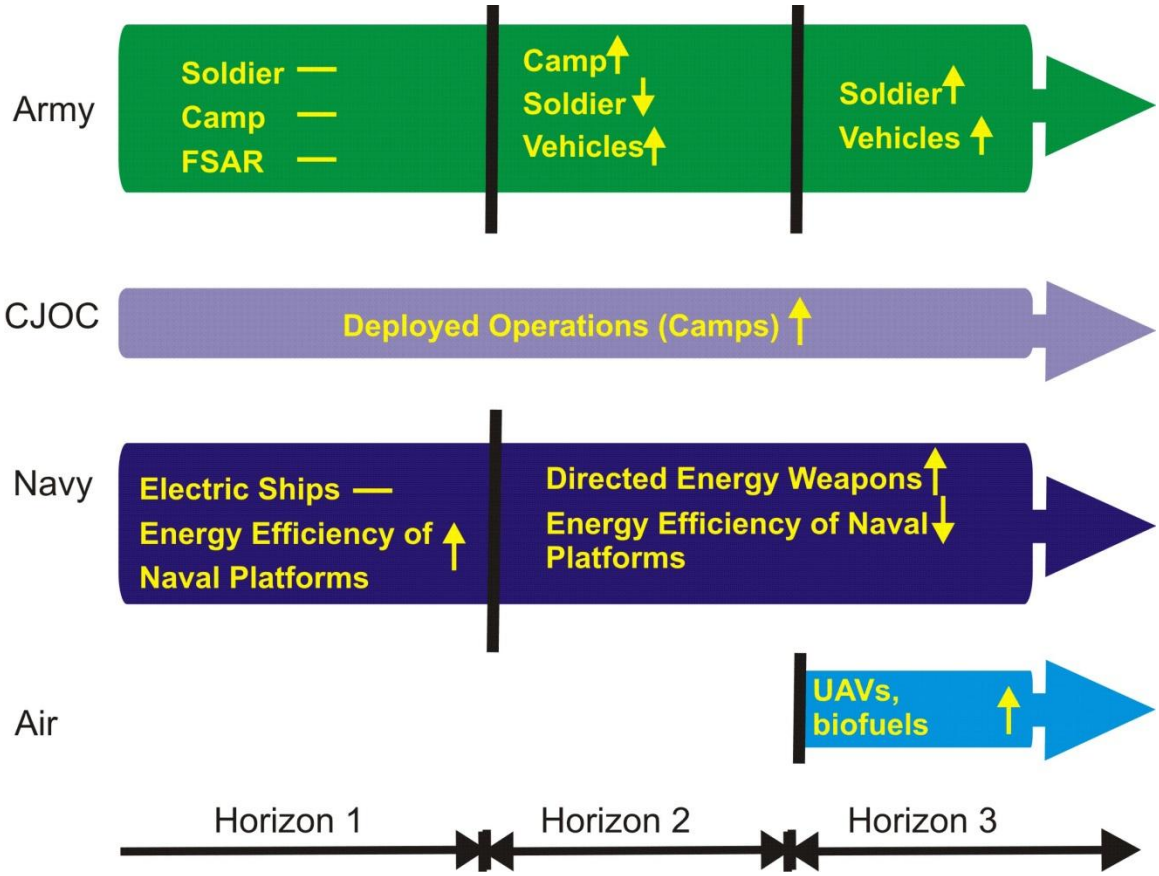


*Figure 3: An overview of current (-) and anticipated requirements for DRDC P&E S&T activities (↑ increasing; ↓ decreasing) derived from consultations with CJOC and DRDC Directorates (Army, Air, Navy).*

# 5 Option Analysis and Recommendations

The following option analysis and recommendations are provided with the understanding that as of FY 2014/15, the current level of resources invested in P&E S&T at DRDC includes two full-time Defence Scientists and approximately $900K in DRDC funds.

## 5.1 Option Analysis

After consultations with the Army, Air Force and Navy portfolios, CJOC and various strategic documents, four possible options for DRDC P&E S&T have been considered taking into account various parameters; for example current resources, internal and external environmental factors (DRDC Senior Leadership oversight, existence of a DRDC Point of Entry for national and international collaborations, etc.), and advantages and disadvantages.

For simplicity and quick reference, the four options considered in this study are illustrated in Figure 4 below followed by their detailed descriptions.

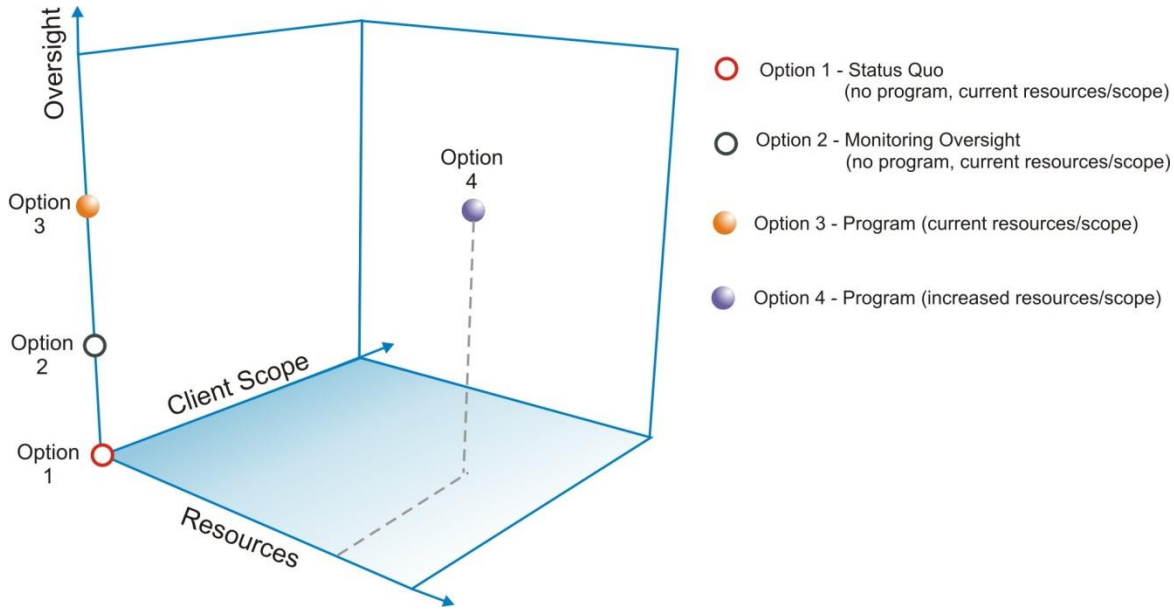


*Figure 4: An illustrative summary of the four options (dashed lines are a guide to the eye).*

**Option 1 – Status quo**

Currently, P&E S&T activities undertaken by DRDC takes place in a stove-piped manner in various portfolios as required and as funding allows without high-level coherent oversight or formal program structure. As the portfolios do not consider P&E to be the top priority, P&E work is done opportunistically when the circumstances arise. Listed below are the advantages and the disadvantages of the current approach.

**Advantage**

1) The advantage of this option is that the research is targeted specifically for each project's requirements resulting in the targeted use of resources and capabilities for maximum impact.

**Disadvantages**

1) The nature of stove-piping dictates that a high-level coherent oversight does not exist. Consequently, it is challenging to objectively quantify the levels of effort and resources dedicated to P&E outside the core P&E group as they are spread thinly across the portfolios with efforts and resources being dynamic throughout the year, and from year to year (depending on the funding levels and the project progress, all of which are also continuously dynamic);

2) The lack of a coherent oversight by Senior Leadership results in the absence of high-level strategic P&E S&T project and resource planning. Therefore, systematic planning for short-term (H1), medium-term (H2) and long-term (H3) P&E S&T does not exist;

3) Resources are thinly spread out to respond to the immediate demands and a goal does not exist to resolve the issues as intended by the DOES energy targets; and

4) As the priority is not given to P&E, this portion of S&T may be easily discarded in favour of another priority despite expressed needs by the DND/CAF clients.

**Option 2 – A monitoring mechanism (not a new program) with current resources**

In this scenario, a mechanism may be established to collate and quantify the levels of effort and resources dedicated to P&E across the portfolios to provide an oversight for Senior Leadership's awareness. This option requires the assignment of personnel resource to regularly track and update the information of interest to Senior Leadership as requested.

**Advantages**

1) As in Option 1, the research is targeted specifically for the project's requirements, resulting in the targeted use of resources and capabilities for maximum impact; and

2) A certain degree of Senior Leadership's awareness is attained.

**Disadvantages**

1) Though a certain degree of high-level oversight now exists, the P&E S&T is still performed by the individual projects within the various portfolios. Coordinated and systematic planning for all the Horizons still does not exist;

2) Resources are thinly spread out to respond to the immediate demands and a goal does not exist to resolve the issues as intended by the DOES energy targets; and

3) As the priority is not given to P&E, this portion of S&T may easily be discarded in favour of another;

4) A designated resource, e.g. a Program Manager, will be required to allocate a certain amount of time to collate information from various Program Managers and to prepare the materials for Senior Leadership; and

5) This option can only be considered a partial solution as information is not centralized, and obtaining up-to-date information from various sources (i.e. various contacts within different portfolios) at short notice may not always be feasible due to various factors, and still does not make the subject of P&E a priority.

**Option 3 – A P&E program with current resources**

Without increasing resources, the current levels that are spread across the portfolios may be consolidated under an established P&E program to be executed and managed within a portfolio, which has a specifically defined objective (Intermediate Outcome) to strategically respond to a departmental mandate. This may be a viable solution as the resources are anticipated to remain unchanged while offering the following immediate positive effects.

**Advantages**

1) The certain and intended impacts, as specified by the program's deliverables, on distinct research targets to benefit DND/CAF would be achieved as resources will be authoritatively co-ordinated and invested to resolve select problems as the extent of the resources allows, and they will be purposefully dedicated to those issues of highest priorities to the DND/CAF clients;

2) There will be the inevitable presence of oversight of the subject provided by the designated Program Manager to provide Senior Leadership with reliable and up-to-date information as this function will be formalized;

3) An important factor in augmenting resource efficiency and effectiveness is continuity in expertise, which impacts both the dimension of cross-cutting topic awareness as well as the time dimension for long-term planning (H3). Continuity can now be better ensured as expertise is now centralized when the P&E S&T activities are centrally managed under a program;

4) Under the centralized oversight and the direction of Senior Leadership, while short-term and medium-term research is being conducted, long-term (H3) planning will also be possible. Proper and diligent long-term planning will help to avoid environmental and technological surprises in the future; and

5) The Program Manager will become the designated Point of Entry in DRDC who is able to have an overview of the program for planning purposes, and to facilitate communications for situational awareness and for establishing and maintaining collaborative efforts with domestic academia and industry, and Canada's allies. Additionally, the presence of the DRDC Point of Entry also has the positive effect of structurally mirroring the Environments (Army, Air Force and Navy), from an organizational point of view, which is an objective that DOES aims to maintain.

**Disadvantage**

1) Even though Option 3 provides many advantages, it does not provide sufficient resources to address current and future demands such as expected by the release of the DOES and the DND/CAF Environments. The existing DRDC resources are already unable to satisfy all the current client S&T requirements as identified in the signed project charters, and the deficiency will only be more pronounced with the implementation of the DOES targets and subsequent increase in the demand levels for P&E S&T.

**Option 4 – A P&E program with increased resources**

With a formal program structure coupled with an increase in resources, Option 4 is targeted towards building internal DRDC capabilities beyond the current two full-time Defence Scientists to respond to a much wider range of client S&T requirements over H1–H3 as identified in the signed Program briefs and Project Charters. Resources imply personnel as well as monetary resources, the various levels of which dictate different work. Without further strategic directions from Senior Leaders, it is not feasible at this point in time to quantify various levels of increased resources and the respective increased amounts of S&T work that can be done. For these reasons, the following option analysis is done without specific quantifications, but will nevertheless provide a qualitative conclusion to the option.

Option 4 certainly achieves all of the effects of Option 3, with enhanced scope and effects, as increased resources will allow the program to expand on the deliverables. Additionally, it will facilitate an extended engagement of the P&E S&T collaborative networks of national and international organizations for better situational awareness and leveraging. Furthermore, at the current resource levels and capabilities, Canada is excluded from access to certain P&E S&T topics, which are classified and sensitive in nature; e.g. S&T work in directed energy weapons, which is identified as a research area within the signed Program Briefs. Increasing resources to P&E S&T within a program structure will build the capabilities required to expand Canada's involvements in these sensitive/classified domains to gain access to the most recent and the most advanced research, the result of which will be augmented resource efficiency and effectiveness for maximum impacts for the DND/CAF clients.

**Advantages**

1) All the advantages mentioned in Option 3 are achievable to enable wider client scope and impacts. Explicitly, more comprehensive long-term planning would be feasible sooner and done with greater confidence so as to be better able to: (a) Provide Senior Leadership with oversight and planning of P&E S&T topics of DND/CAF priorities; (b) Develop capabilities in DRDC to respond to H3 issues; e.g. anticipate and address disruptive technologies; and (c) Increase the levels of partnership with Canada's allies;

2) Notably, increased international partnerships will lead to increased international accesses to the currently unattainable sensitive/classified information, resulting in rapid augmentations of the leveraging effects and better positioning Canada to respond to sensitive/classified/strategic/unique P&E issues; and

3) There may now be the ability to address P&E S&T requirements for other DND/CAF clients that are not currently identified or accommodated within the DRDC portfolio structure; e.g. ADM(Mat) and ADM(IE).

**Disadvantage**

1) In the current environment where resources are scarce, allocating additional resources to respond to departmental and governmental mandates, such as DOES, will be challenging and requires careful considerations against other DND/CAF S&T priorities.

## 5.2 Recommendations

Based on the consultations, option analysis, and the anticipated continuing constraints on budgetary resources, the following recommendations are made:

1) It is recommended that Option 3 be adopted to identify a new Power & Energy Program with its own Intermediate Outcome and Immediate Outcomes (Deliverables) to fulfill current client S&T requirements as well as to satisfy certain environmental factors such as DRDC Senior Leadership oversight, existence of a DRDC Point of Entry for national and international collaborations, etc. Although Option 3 is an improvement to the status quo, it is, however, insufficient to meet current client S&T requirements as identified in the signed Program Briefs and Project Charters that are currently not funded as well as the additional expected requirements from the endorsement of the DOES energy targets and the release of the DOES;

2) It is also recommended that the advantages of Option 4 be considered to further develop capabilities should additional resources become available as client demands will certainly continue to increase. The additional resources will augment Canada's involvements in international activities with allies and partners in P&E subject areas that are sensitive/classified/unique to enable anticipations of emerging/disruptive technologies and facilitate accesses to the most recent and the most advanced research; the result of which will be augmented resource efficiency and effectiveness for maximum impacts for the DND/CAF; and

3) Any increase in resources and program activities, as described in Option 4, should be planned in a measured and incremental manner against capabilities that exist and those which may be needed within DRDC, while taking into account the ability to execute MOU agreements with external partners, and client S&T requirements.

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# Annex A DND/CAF Energy Consumption [2]

Figure A.1 provides, for the first time, DND/CAF's best estimate of the proportion of energy used by the fleet in each Environment (Army, Air Force and Navy) out of a total of 12 petajoules (PJ) per year for both domestic and expeditionary operations. In reverse order of magnitude of energy used, the consumptions are as follows: Canadian Army (CA) 17%, Royal Canadian Navy (RCN) 21% and Royal Canadian Air Force (RCAF) 62%.

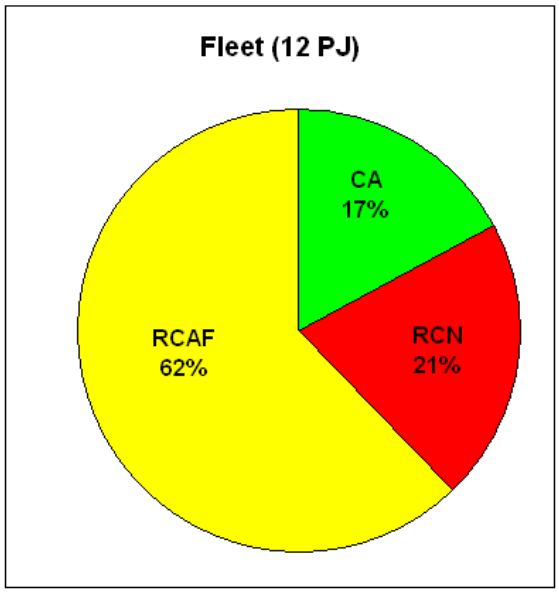


*Figure A.1: Average over three years of yearly domestic and expeditionary energy per Environment.*

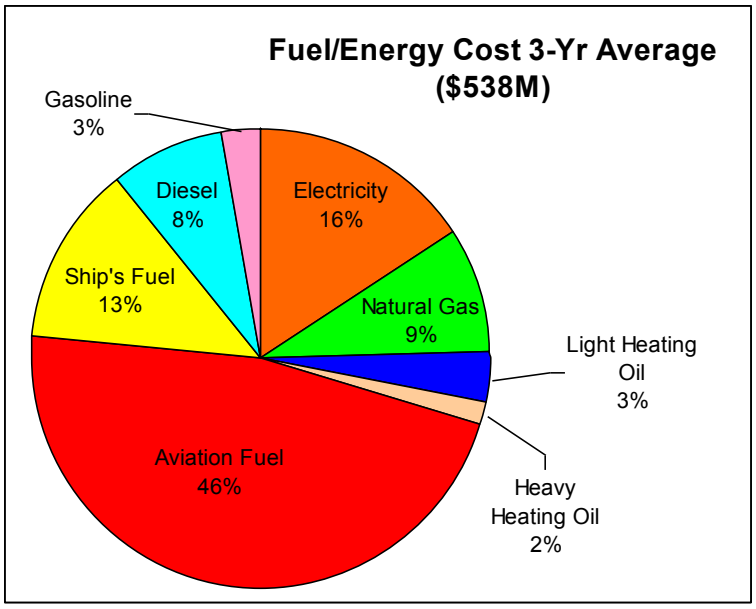


*Figure A.2: Average over three years of yearly domestic and expeditionary energy cost proportion.*

Figure A.2 above provides the yearly relative proportion of types of energy for DND/CAF uses as averaged over three years. From the total cost of 538 million Canadian dollars, about 70% of the cost is for the fleet and 30% for the buildings. The large difference in percentage between the energy quantities (52%–48%) and costs (70%–30%) is dominantly driven by the low cost of natural gas in Canada. The aviation fuel represents about 66% of the total fleet fuel cost which is assumed to be the sum of the following: gasoline (3%), diesel (8%), ship's (13%) and aviation (46%), for a total of 70% for the fleet fuel cost.

The following graph illustrates the trend of the total energy expenditures, where domestic, training and expeditionary operations are considered. The graph includes data for buildings and for fleets over the 14-year period as reported for energy related GLs (general ledger accounts) in Defence Resource Management Information System (DRMIS). DRMIS reports all expenditures charged to a given GL account (domestic and foreign), and based on the information available in the financial system, it is not clearly identified whether the payments were related to domestic or international operations.

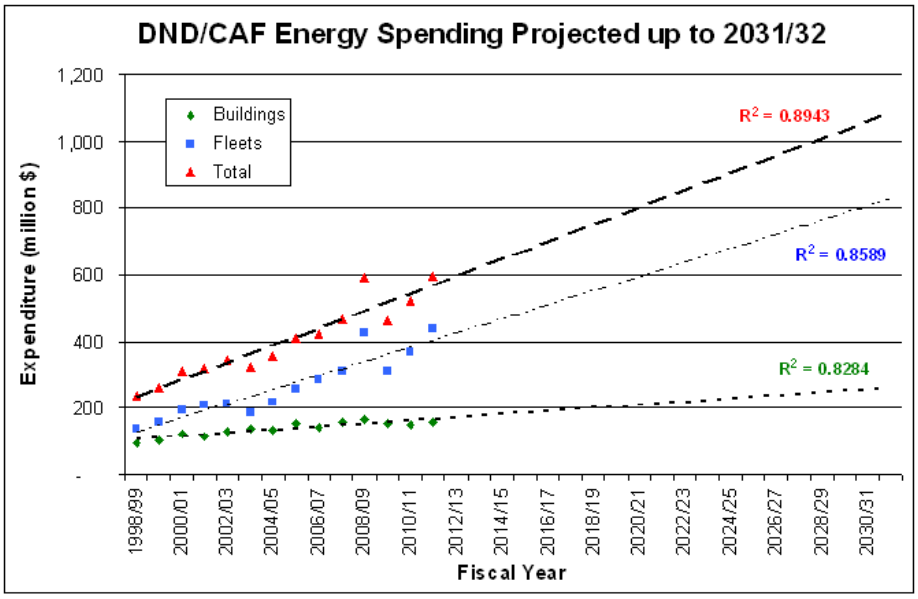


*Figure A.3: Trends of DND/CAF total cost for energy according to the 14-year data and a 20-year projection based on these trends.*

If the fleet energy price is assumed to increase at the same rate as for the last 14 years, approximately doubling in each decade, then the total CAF fleet energy spending will have increased from approximately 140 million dollars in fiscal year 1998/99 to 800 million dollars in 2030/31; about six times as much if no significant corrective actions are taken. The total DND/CAF energy cost (538 million in 2010–11) follows a similar trend from about 240 million to 1,100 million dollars by 2031, which is about five times as much.

In order to provide a more complete picture of the defence operational energy used by Canada, the following simulation result (For details on simulation methodology, please see "DOES Supporting Report by Paul Labbé et al.") shows the proportion of energy used per type of fuel. This result combines several thousand point estimates using specific force compositions that went through all phases: deployment, force employment and redeployment.

The simulation results can be summarized as follows: The total demand was 260 million litres (ML) over 3 years with the following fuel type distribution, aviation fuel (54%), ship's fuel (8%) and diesel (38%) as illustrated in Figure A.4 below. Note that the low amount of ship's fuel is due to the data used in the simulation runs which were selected from real CAF expeditionary operations during the last 10 years.

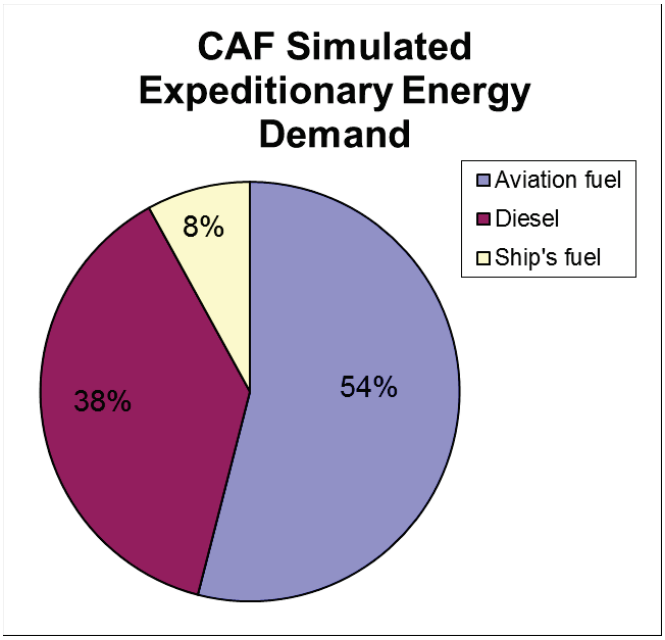


*Figure A.4: Simulation results using selected scenarios of operations over three years.*

# Annex B International Activities/Partnerships

1. **TTCP MAT TP8 – Power & Energy – Materials & Systems**

A new panel was created in The Technology Cooperation Program (TTCP) in 2007 under the Materials (MAT) Group. With multi-service representation from the US in particular, it allows for cross-cutting activities on electrical power generation and storage (with a tactical focus).

**Benefit**

DRDC gains information access into much larger programs working in several energy specialties. Burden sharing assignments have resulted in direct cost savings to DRDC program in the Panel business plan ($250K in 2013/14). A current example is an operating assignment on the round robin evaluation on portable fuel cells. This helped DRDC save/avoid expending about $500k on contract with industry on soldier power project in the Army portfolio (under Advanced Soldier Adaptive Power) from FY 2013/14 to 2015/16. These funds were then spent more strategically on the contract on soldier power/data integration aspects to speed up Phase I effort so that about 40% de-scoping of the contract could be achieved in Phase II.

**Future High Priority International Activity**

TTCP has proven to be beneficial for DRDC and is an important international engagement for the DRDC Power & Energy domain. With modest capability increase, it will be possible to extend current activities that are Army-focused to include more Navy elements. As DRDC may exchange S&T access to sometimes confidential (secret) information in both materials-related and prototype power source systems, it is beneficial for DRDC to continue involvement in this Panel. This technology area lends itself to develop burden sharing in the Army soldier program (Operational Energy), novel power sources and other areas of lower maturities that are not covered in DRDC programs or internationally under other agreements.

**2. TTCP JSA AG-16 (New) Operational Power and Energy Research & Analyses (OPERA): Business Plan, 2014 to 2017**

A new AG-16 mandate was requested by The Technology Cooperation Program (TTCP) Joint Systems Analysis (JSA) Group in 2014. With multi-service representation from the five countries, the new group addresses metrics and analyses of cross-cutting activities on operational power and energy for national and international joint operations.

**Benefit**

As exemplified by the benefits to DND/CAF in developing strategies such as the first DND/CAF Operational Energy Strategy (DOES) during the initial JSA AG-16 mandate, similar benefits to Canada via DRDC participation is expected under the new JSA AG-16 mandate. The following costs represent all the costs of managing and delivering the full spectrum of planned AG-16 activities across all five countries:

- Annual average direct staff costs will be about US$34.4K per country per annum; and

- Annually, the total leveraged value of national programmes exposed through AG-16 is expected to be US$13.86M and will result in direct cost avoidance for the five countries of an estimated US$4M, although the ultimate savings to national defence through a reduction in hydrocarbon based fuel usage will amount to tens or hundreds of millions of US dollars.

AG-16 activity delivers a systems approach to energy that ensures that decision-makers across TTCP nations' defence communities are able to deliver their required capability outputs and effects without being constrained by energy price volatility or its availability in front line operations. Reducing military dependence on fossil fuels will not only lower defence operating costs but will also improve mission effectiveness and operational capabilities by reducing the logistics burden to front line operators. The value of this is difficult to assess in monetary terms, but will ultimately amount to tens or hundreds of millions of US$, and thus represents a highly cost-effective investment for participating nations.

**Future High Priority International Activity**

The following TTCP strategic challenges have been a major focus in guiding AG-16 activities for a number of years and will continue to be addressed in this new group:

- **Interoperability/Energy Interoperability**: This domain includes: (a) The augmentation of the ability of allies to work together using common power and energy standards and architectures, and b) the maintenance of the Energy Capability Metrics that are common across the countries;
- **Agility**: Commonality of standards and energy metrics to improve logistics;
- **Affordability**: Reducing the cost of energy systems and improve the resilience to market fluctuations;
- **Effective Decision Making**: Energy system Models and Tools to better inform decision makers in acquisition force planning and assessments; and
- **Program Fragility**: In the current environment of fiscal austerity, program funding is at risk, thereby affecting the overall S&T work, program management (including travel), the ability to leverage and ultimately the delivery of the program itself.

Addressing these challenges requires AG-16 to share the associated burden by drawing on the complementary strengths of the members, of which the AG-16 has performed an assessment against the challenges in its 2014–2016 programme activities through a capability audit of defence energy research. The assessment process will result in a potential portfolio for exploitation that will be ranked by the ability of the proposed research to impact the Common Strategic Challenges before approvals are granted for resources to commence S&T work.

### 3. NATO Army Armaments Group (NAAG) Land Capability – Dismounted Soldier Systems (DSS)

This NATO military group benefits from DRDC expertise and DRDC has leveraged international resources in portable power under the Power Team of Experts working group. DRDC contributed to the completion of two key electrical connectivity standards (STANAG 4619 & 4695) that

Canada will ratify. It will be referenced and applied to future standards both internationally and nationally for small arms platform and C4I (Architecture) systems.

**Benefit**

DRDC's involvement in this activity ensures interoperability with allies on future soldier, vehicle systems etc. that require electrical power standards. Also, it allows information access into larger programs in soldier systems. This access has provided excellent guidance into future procurement programs in the Integrated Soldier Systems Project (ISSP), and advice on requirements and bidder evaluation criteria has been exploited from lessons learned in this NATO working group (several DRDC Scientific Letters (SL) have been written on soldier system topics).

**Future Medium-High Priority International Activity**

ISSP will be doing a Phase III procurement of the soldier system in the 2018–2020 timeframe and requires further technical advice on carrying, storing, transporting future power consumers in the battlefield and deployed operations for extended mission duration and higher power demands than in the past. The soldier system is a high priority for the Army and important deliverable by DRDC under SoSE (Soldier Operational Effectiveness) Project. This engagement provides valuable access to information from allies on future soldier systems designs and concepts. In Horizon III the Army seeks technical advice on soldier systems integration, but also more effort on other mobile platforms that require interoperability. Transitioning effort to vehicle systems (Combat Systems Army project) will occur in Horizon III.

**4. NATO STO – Power & Energy Related Working Groups**

Activities in Power and Energy fall into the platform areas of interest. In the past, reports with DRDC authorship has been accepted by three STO Panels; AVT (Advanced Vehicle Technologies), SCI (Systems Concepts and Integration and SET (Sensors and Electronics Technologies). As an example, the SCI RTG-173 – Future Weapons Systems won a STO award for its publication in 2011. Dr. Ed Andrukaitis was lead author/editor of power source section. Results were exploited in the current Army portfolio Future Small Arms Replacement (FSAR) project and also resulted in drafting a STANAG (currently in ratification) on a weapons powered rail standard for NATO.

**Current activity:**

1. NATO STO SET 203 – "Soldier and sensor power sources". The working group was established in 2013 focusing on technology assessment for power for soldier systems and remote sensing, etc. The power demand requirements and integration of power on future soldier systems is part of the SoSE (Soldier Operational Effectiveness) Project;

2. The scope of work of NATO STO AVT-227 is "Balancing energy storage with safety in large format battery packs". The working group was established in 2014 and has become very topical for lithium-ion safety issues in commercial aircraft given several events that occurred recently. DND and allies will be using higher energy density batteries and thus requires the military to understand the proper usage, performance requirements and safety procedures to implement energy storage as they appear in new equipment and devices; and

3. A new proposal is in definition to be submitted in December 2014 to NATO Science for Peace & Security (SPS) – Develop and Improve Energy Technologies (DIET). This is a proposal for a new multi-national project focused on integrating S&T developments on operational energy for future NATO camps, and the objective of the proposal is to create a technology prototype on test-bed/facility to introduce/test/validate new energy production/storage efficiency technologies for a deployed camp application.

**Summary:**

NATO working groups remain a major access mechanism to S&T work done by Canada's allies in this diverse technology sector. The work is technology focused, based on the platform or problem area that it is trying to address and is currently focused on Army issues in-line with the DRDC Army Portfolio. Numerous examples in cost avoidance, technology watch and procurement requirements have been demonstrated from previous STO working groups (received an award for SCI RTG-173 – Future Weapons Systems).

## 5. Bilateral Agreements with Power & Energy

- New CA/UK Project Arrangement (PA) on Soldier Systems: A new bilateral is being drafted in for the Army project Soldier System Effectiveness (SoSE) which has an important P&E requirement. The UK recognizes the high importance of energy for dismounted operations and this will be set up as a burden sharing effort with Defence S&T Laboratory DSTL in Porton Down, UK.
- North American Technology and Industrial Base Organization (NATIBO): This organization is a bilateral where Canada and the US collaborate via a working group that focuses on electrochemical power sources since 2011 to advance S&T in operational energy. The US considers operational energy a high priority and an operational enabler and the US has a very robust industry sector, where Canada procures most of its energy storage (such as batteries), and electrical generation equipment and components, etc. DND has benefited from this bilateral as DRDC's involvement in this bilateral gives DND direct access to P&E S&T developments and the US military investment portfolio in this sector. Furthermore, it has benefited the Canadian industry, as it has provided the Canadian industry with access to US programs and investment since the US Army is the biggest customer for battery and fuel cell companies that DRDC had supported in the past. Additionally, this umbrella bilateral leads to further access to other US government-only meetings and working groups where Canada is the only non-US participant/attendee. Examples of the said government-only meetings and working groups include the annual Lithium battery safety working group), National Defense Industry Association (NDIA), etc.

# Annex C Evidence of Resource Leveraging and Client Impacts

*Table C.1: Evidence table for resource leveraging and client impacts by P&E group.*

| Project Description | Duration | Sourcing Strategy | Impact for the Client |
|---|---|---|---|
| **Direct Client Support** | | | |
| Sonobuoy and Emergency Locator Transmitter (ETL) Battery Life Extension. Client: DGAEPM. | 2003 – 2010 | | Cost savings / cost avoidance of ~$4M through life extension of Sonobuoy and ELT batteries [21]–[23]. |
| Power Requirements for Soldier Devices and Performance of AA Batteries. Client DLR-5 and ISSP. | 2006 – 2007 | | Cost savings / cost avoidance of ~$400K through better management of power during operations [24], [25]. |
| TCCCS Radio Battery Investigation. Client DLSCM. | 2002 – 2014 | | Cost savings / cost avoidance of ~$1.8M through expert advice on battery issues [26], [27]. |
| **In-house Projects** | | | |
| Advanced Soldier Adaptive Power (ASAP) Project. Client DLR-5 and ISSP. | 2008 – 2016 | Partners: DRDC ($5.9M), NRC ($75K per year), Industry (Rheinmetall, in-kind ~$500k) | Goal: reduce soldier burden through improved power solutions for future soldier systems. |
| ManADO – Sustain and Reduce Energy for Deployed Operations. Client: DLR7, CALWC, CJOC, DCSEM. | 2014 – 2019 | Partners: DRDC ($2M), NRCan, NRC | Goal: reduce camp fuel consumption by 40–50%. Introduce new technology to optimize cold-weather camp design. |
| Alternative Power and Energy Solutions for Reduced-Diesel Arctic Infrastructure. Client: 1 Cad Air Div. | 2011 – 2015 | Partners: DRDC ($900k), PERD ($440K), 1 CAD ($600K) | Reduction of operational energy costs and GHGs. Implementation of recommendations of report in FY 2014/16 [ADM(IE)] results in ~22% fuel reduction or 22 HERC OP Boxtop flights. Reduced wear and tear on aircraft [28], [29]. |
| Winter Camp Demonstration. Client: ADM(IE). | 2013 | Partners: DRDC, ADM(IE) ($1M) | CJOC using results for Defence Operational Energy Strategy report and as CAN contribution to NATO Smart Energy Team (SENT). Model to be used in proposed NATO camp of the future project est. €5M. |

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# Annex D Current Projects (detailed descriptions)

Listed below are the projects that are currently funded in the Army and the Air Force portfolios and that have P&E S&T requirements. The following information (outcomes, deliverables etc.) has been extracted from the signed Program Briefs and Project Charters.

## D.1 Army Portfolio

**a) Program: A 1 – The Soldier**

**S&T Outcome(s):**

- The Army will improve soldier effectiveness by increasing protection, weapons effects, mobility, self-sufficiency and resilience while decreasing burden, in an integrated human-centric soldier system.

**Soldier Systems Effectiveness and Protection deliverable(s):**

- Improved self-sufficiency (without re-supplying for the mission duration) through increased energy efficiency within acceptable added weight by demonstrating an advanced wearable power system that augments a dismounted soldier's performance, autonomy, sustainability and effectiveness in dispersed operations (by 2015).

**Current Status:**

- This activity is a follow-on activity to the Advanced Soldier Adaptive Power (ASAP) project (02sl). It has been funded to FY 2015/16 for Phase II deliverables with Rheinmetal Canada Inc.

**DND Client:**

- ISSP (Integrated Soldier System Project) major capital project;
- Director Land Requirements 5 (DLR 5);
- Tactical Command, Control and Communication System (TCCCS); and
- Canadian Special Operations Forces Command (CANSOFCOM).

**Delivery Capacity:**

- *Collaboration* with ISSP (Integrated Soldier System Project) major capital project and DLR 5 (Soldier systems) and, via MOU, with NRC. Future Small Arms Replacement (FSAR) project; and
- *Access* through NRC and International agreements (Annex B).

**Background:**

Portable power is the most expensive energy on a kilowatt-hour (kW-h) basis in the battlefield. Operations in Afghanistan highlighted the consumption of electrical power for soldiers to perform their tasks. Batteries were consumed by the palates with the cost and risk of transporting these consumables into operation. The power adds significant weight and cost of operation to the soldier. Any reduction in7 this energy burden is critical to future soldier capability as these are all electronic devices. It is for this reason that DLR 5 and ISSP rates power as the number one issue for the development of a modern soldier system. On average, the soldier system project estimates it will need to procure an estimated $5–7M worth of batteries and new charging infrastructure annually in operation. Portable power (in the form of batteries) is also being used/consumed by other projects in ADM(Mat) that use electrically powered devices in the range of about $5M/year in DND.

**Significance for Defence and Security:**

The future capabilities proposed by the Integrated Soldier System Project (ISSP) for Cycle III are mostly electronics based, requiring electrical power and data storage, reception and transmission. To satisfy future soldier system mission duration requirements, weight and sustainability constraints must be met so that operations over the complete range of environmental conditions are supported and power costs minimized. Also, the system must fit seamlessly within the Army architecture and an integrated approach to power and data management needs to be implemented. Several options, for power and data protocol, offer advantages/disadvantages to the dismounted soldier. Thus, proper integration with power management and understanding future power/data demand will aid the CAF in making the best procurement choices.

**b) Program: A 4 – The Force**

**S&T Outcome(s):**

- Manoeuvre through Adaptive Dispersed Operations (ManADO) – The Army will improve the potential to manoeuvre over ADO through time/place/purpose in the conduct of tactical activities. This means increased speed and mobility, self-sufficiency, access to fires, C4ISR[5] resources, more responsive medical and logistical support, more capable junior leaders, and the deployment of strategic resources to the theatre.

**Manoeuvre through Adaptive Dispersed Operations deliverable:**

- Improved tactical logistics through reduced demand on fossil fuel and better information management by the provision of camp power and transition to sustainable (reduction of petroleum use) and economical (no increase in cost) supplies of P&E in support of Canada's Army (by 2015).

**Current Status:**

- This activity has been funded to FY 2018/19.

[5] Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance.

**DND Client:**

- DLR-7;
- CJOC; and
- Director Computer Systems Engineering and Maintenance (DCSEM).

**Delivery Capacity:**

- *Collaboration* with DLR Modern Power Sources capital project and MOU with Natural Resources Canada and the NRC. In-kind support from the Army and CJOC for loaning/use of existing equipment in CAF inventory will be used during involvement in CAF exercises; and
- *Access* through NRC, the Panel of Energy R&D (PERD) Program and International agreements (Annex B).

**Background:**

It has been estimated that fossil fuel in operations costs significantly more (two to five times) depending on the locations of the operations, due to an increased logistics burden for transportation. This increased burden hampers CAF capability as significant effort is required to secure needed energy to meet the ADO (adaptive dispersed operations) mandate [30]. Future technologies with the employment of co-generation and waste energy recovery can significantly reduce the consumption of the fossil fuel that is hard to resupply thereby making future operations more sustainable. Energy self-sufficiency through efficiency, harvesting and renewable methods need to be explored to achieve operational capability targets in the future. This program activity is targeted towards deployed power solutions to ensure that the CAF has secure, affordable, and sustainable energy in deployed operations (mobility). The goal is to enhance the Army's ability to manoeuvre and preserve freedom of action through a significant reduction in the environmental and logistics burden, particularly, the movement and delivery of energy (fossil fuels for vehicles and heating/cooling deployed camps etc.).

**Significance to Defence and Security:**

Advanced energy storage and conversion technologies can improve tactical logistics through reduced demands on fossil fuel and better information management by the provision of camp power and transition to sustainable (reduction of petroleum use) and economical supplies of P&E in support of Canada's Army.

## D.2 Air Portfolio

### a) Program: AF 4 – Air Agile

**S&T Outcome(s):**

- Through the Air Agile S&T Program, the RCAF will have better tools to employ efficient and effective force generation and enabling capabilities, including pilot and aircrew training.

Note that the Air Agile Program also includes all the aspects of system sustainment, Human performance, Power and Energy and Expeditionary Support.

**Force Generation and Support Program deliverables:**

- Efficiency of engines, structures, lighting, etc. will be improved, alternate sources of energy sought, and interoperability with Canada's allies who are also seeking and migrating to alternate P&E sources must be maintained. Economies may be realized in consumption and wear of components, but equally, compliance and certification issues must be addressed. Micro-grids, bio-fuels, photovoltaic cells, reliance on external (non-Canadian) sources, distribution and delivery issues, and environmental impacts are all issues that will be considered within this program. ADM(IE) is assuming responsibility for infrastructure, so the project will only deal with infrastructure concerns which are Air Force specific and which do not fall within ADM(IE)'s areas of interest. This project also addresses Air Force fuels, in particular, preparing for new fuels and new processes. Topics of interest include working with OEMs to evaluate fuels and processes from Canada and from key Allies, as well as exploiting the environmentally improved impact (diminished negative effects) of the new fuels.

**Current Status:**

- This is the final year of the four-year project, which is scheduled to conclude on the 31st of March, 2015.

**DND Client:**

- A4CE (1 Canadian Air Division).

**Delivery Capacity:**

- *Collaboration* with 8 Wing Trenton, CanmetENERGY and NRC; and
- *Access* through Geological Survey of Canada, CanmetENERGY, NRC, Environment Canada and Department of Fisheries and Oceans.

**Background:**

In 2011, DRDC was tasked by the Arctic Management Office of 1 Canadian Air Division to identify alternative P&E options and strategies to reduce the fuel burden and thus operational costs for arctic infrastructure with a focus on CFS Alert. On an annual basis, CFS Alert consumes approximately 2 million litres of Jet Propellant 8 (JP-8) fuel to sustain CAF personnel and operations at the site. CFS Alert, by reason of its extreme northerly location, is challenged by a harsh environment, extreme arctic climate and remoteness. These factors inherently impose a demanding energy budget and logistics burden at significant financial cost (~ $5–7/Litre of fuel) with negative impacts to the environment for RCAF operations.

A "Whole of Government" approach has been adopted in this project to leverage existing resources as well as to tap into the range of expertise that currently exists within OGDs to achieve the desired outcome, which is to reduce operational costs and the environmental impacts

stemming from high fuel-use for RCAF arctic infrastructure (and by extension the greater CAF) in Canada's North. To realize this outcome, four main objectives have been identified to be accomplished, which are:

1. Determine the baseline energy use at CFS Alert through demand-side smart metering and an energy audit;

2. Assess the viability of wind, solar, geothermal, hydro and sea-water heat pump technologies as well as other options that may emerge;

3. Develop a strategy to reduce diesel-use based on the baseline energy use and technology assessments; and

4. Derive a common methodology for identifying alternative sustainable P&E options that can be applied to other Arctic locations such as Resolute Bay, Eureka or the North Warning System.

**Significance for Defence and Security:**

The aim of this work is to identify and assess alternative P&E options targeted towards reducing the reliance on fossil fuels used to meet electrical and thermal demands for the sustainment of arctic infrastructure and operations. In remote areas such as the arctic where geographical access and harsh climate conditions pose significant challenges, the provision of energy to sustain personnel safety, infrastructure and operations come at a high monetary cost. Within the defence and security context, this project supports the objective of energy sustainability and security by reducing the environmental impacts and operational costs of the Royal Canadian Air Force in the arctic. The results of this work lay the foundation of a strategy to reduce fuel use, initially, through energy saving measures, followed by the longer-term implementation of alternative options such as renewable energy (e.g. solar) as technologies become mature for such environments. This will translate into costs savings, reduction of greenhouse gases as well as yearly flight rates, thus, allowing the reprioritization of flight assets and reduced wear and tear on aircrafts.

# List of symbols/abbreviations/acronyms/initialisms

| | |
|---|---|
| AVT | Applied Vehicle Technology Panel |
| C4ISR | Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance |
| CJOC | Canadian Joint Operations Command |
| DCSEM | Director Computer Systems Engineering and Maintenance |
| DLR | Director Land Requirements |
| DOES | Defence Operational Energy Strategy |
| FBCE | Fully-Burdened Cost of Energy |
| MAT | Materials |
| NAAG | NATO Army Armaments Group |
| P&E | Power and Energy |
| PERD | Panel of Energy R&D |
| SET | Sensors & Electronics Panel |
| STANAG | Standardization Agreement |
| STO | (NATO) Science and Technology Organization |
| TCCCS | Tactical Command, Control and Communication System |
| TP | Technical Panel |

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DRDC Power & Energy S&T Option Analysis and Recommendations : A Response to Cross-Cutting Client S&T Requirements

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This Document Report on an option analysis and ensuing recommendations for the way-forward for DRDC Power and Energy (P&E) S&T activities at the request of ADM(S&T). This request also coincides with the development of the DND/CAF Defence Operational Energy Strategy (DOES), which is an L0 initiative led by ADM(IE) that identifies specific energy-related targets to be achieved by DND/CAF with the aim of achieving greater operational energy efficiencies while maintaining, or improving, existing DND/CAF capabilities. The option analysis and subsequent recommendations are based on an assessment of the current state of P&E S&T activities within DRDC as well as consultations with strategic documents (including the DOES), the Canadian Joint Operational Command (CJOC), and the DRDC Directorates of the Army, Air Force and Navy portfolios. Four scenarios were investigated for the option analysis, which ranged from maintaining the status quo with current resources to having a formal program structure with significantly increased resources.

Based on the consultations, option analysis, and the anticipated continuing constraints on budgetary resources, the following recommendations are made:

1) It is recommended that a new Power and Energy Program be identified with its own Intermediate Outcome and Immediate Outcomes (Deliverables), to fulfill Horizon 1 and Horizon 2 client S&T requirements while taking into account the intents of the DOES (Option 3);

2) It is also recommended that capabilities in the P&E domain be developed within a program structure should additional resources become available (Option 4). This will enable DRDC to meet longer-term client P&E S&T requirements (Horizon 3) and to allow the engagement of subject areas that are sensitive/classified/strategic/unique in nature (e.g. directed energy weapons) as well as to anticipate emerging/disruptive technologies in this domain; and

3) Any increase in resources and program activities, as described in Option 4, should be planned in a measured and incremental manner against capabilities that exist and those which may be needed within DRDC while taking into account the ability to execute MOU agreements with external partners, and client S&T requirements.

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Ce document présente une analyse d'options et les recommandations qui en découlent quant aux prochaines étapes des activités de S & T de RDDC en matière d'électricité et d'énergie, à la demande du SMA(S & T). Cette demande coïncide avec l'élaboration de la Stratégie énergétique opérationnelle de la Défense (SEOD) du MDN/des FAC, une initiative de N0 dirigée par le SMA(IE) qui établit les cibles énergétiques que doivent atteindre le MDN/les FAC pour réaliser de meilleures économies d'énergie opérationnelles tout en maintenant ou en améliorant les capacités existantes du MDN/des FAC. L'analyse d'options et les recommandations qui en découlent se fondent sur une évaluation de l'état actuel des activités de S & T en matière d'électricité et d'énergie au sein de RDDC et sur la consultation de documents stratégiques (y compris la SEOD), du Commandement des opérations interarmées canadiennes (COIC), et des directions des portefeuilles de l'Armée, de l'Aviation et de la Marine au sein de

RDDC. Quatre scénarios ont été examinés dans le cadre de l'analyse d'options, allant du maintien du statu quo avec les ressources actuelles à la création d'une structure de programme officielle dotée de ressources considérablement accrues.

En fonction des consultations, de l'analyse d'options et de la poursuite prévue des réductions budgétaires, les recommandations suivantes ont été formées :

1) On recommande l'élaboration d'un nouveau programme d'électricité et d'énergie comprenant ses propres indicateurs intermédiaires et résultats immédiats (livrables), pour répondre aux besoins en S & T des clients des horizons 1 et 2, tout en tenant compte des intentions de la SEOD (option 3);

2) On recommande aussi que les capacités dans le domaine de l'électricité et de l'énergie soient développées en une structure de programme si des ressources supplémentaires deviennent disponibles (option 4). De cette façon, RDDC pourra répondre aux besoins à long terme des clients S & T en matière d'électricité et d'énergie (horizon 3), permettre l'exploration de domaines délicats/classifiés/stratégiques/uniques en leur genre (p. ex. les armes à énergie dirigée) et prévoir les technologies nouvelles/perturbatrices dans ces domaines;

3) On recommande que toute hausse de ressources et d'activités de programme, comme il est décrit à l'option 4, soit planifiée de manière raisonnable et progressive en fonction des capacités qui existent et de celles qui pourraient être requises au sein de RDDC, tout en tenant compte de la capacité d'exécuter les protocoles d'ententes avec les partenaires extérieurs et des besoins S & T des clients.

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Power, Energy, Operational Energy, Operational Energy Efficiency, Energy Targets, Energy Security and Operations, Defence Operational Energy Strategy